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Geahgan

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(54) **LIGHT GUIDE FOR BACKLIGHT**

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This patent is subject to a terminal disclaimer.

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(51) **Int. Cl.**

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G06F 3/03	(2006.01)
G06F 3/038	(2013.01)
G06F 3/0354	(2013.01)

(52) **U.S. Cl.**

CPC ***G06F 3/042*** (2013.01); ***G06F 3/0325*** (2013.01); ***G06F 3/0386*** (2013.01); ***G06F 3/03542*** (2013.01)

(58) **Field of Classification Search**

CPC G06F 3/0412; G06F 2203/04109; G06F 3/0421; G06F 3/086; G06F 3/03545; G02B 26/02

USPC 345/173, 175, 179–183; 362/612; 349/65

See application file for complete search history.

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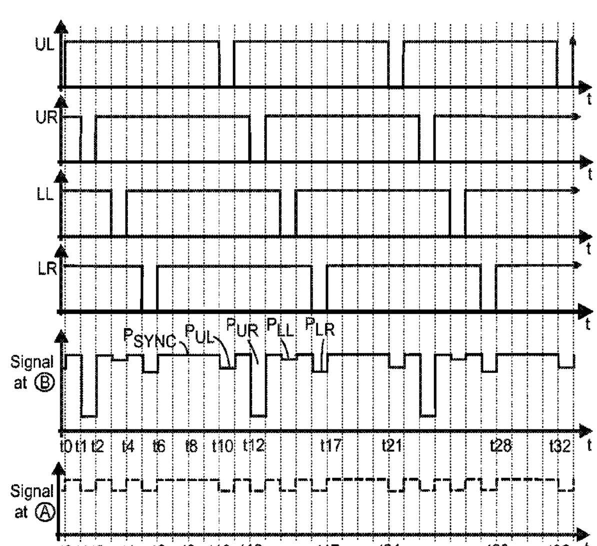
(57) **ABSTRACT**

The present invention provides a light guide for an electronically addressable display (such as an LCD) that mixes optical signals from a plurality of emitters, and mixes these signals to produce, for positions on the display, position-unique signals. A stylus or other receiving device may determine its position relative to the electronically addressable display by analyzing the position-unique signals.

7 Claims, 7 Drawing Sheets



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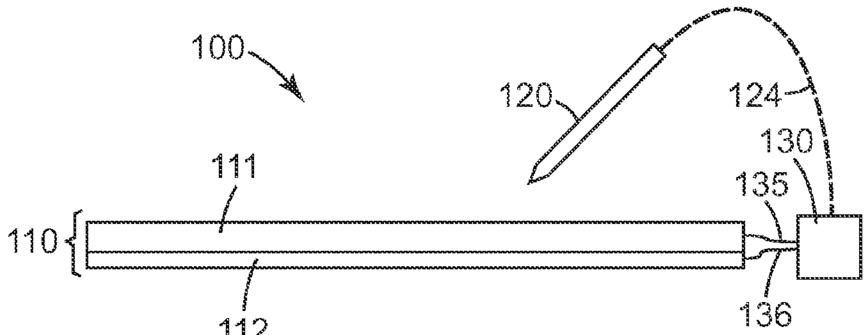


Fig. 1A

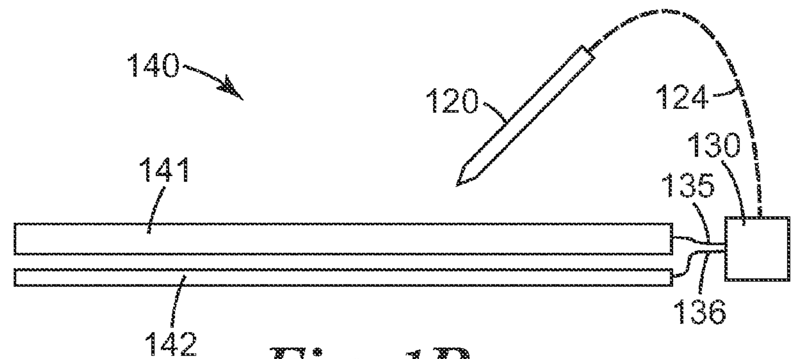


Fig. 1B

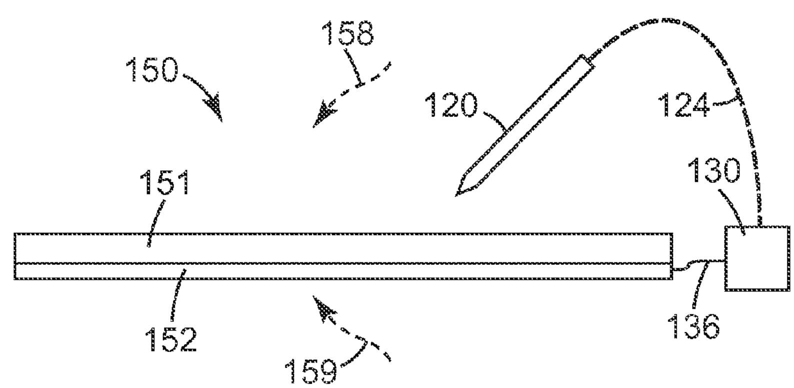


Fig. 1C

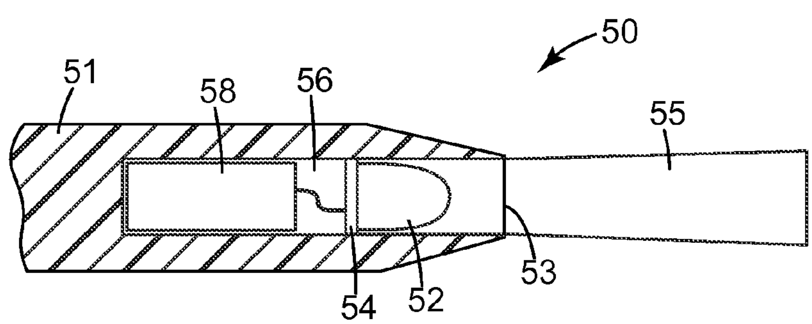


Fig. 2

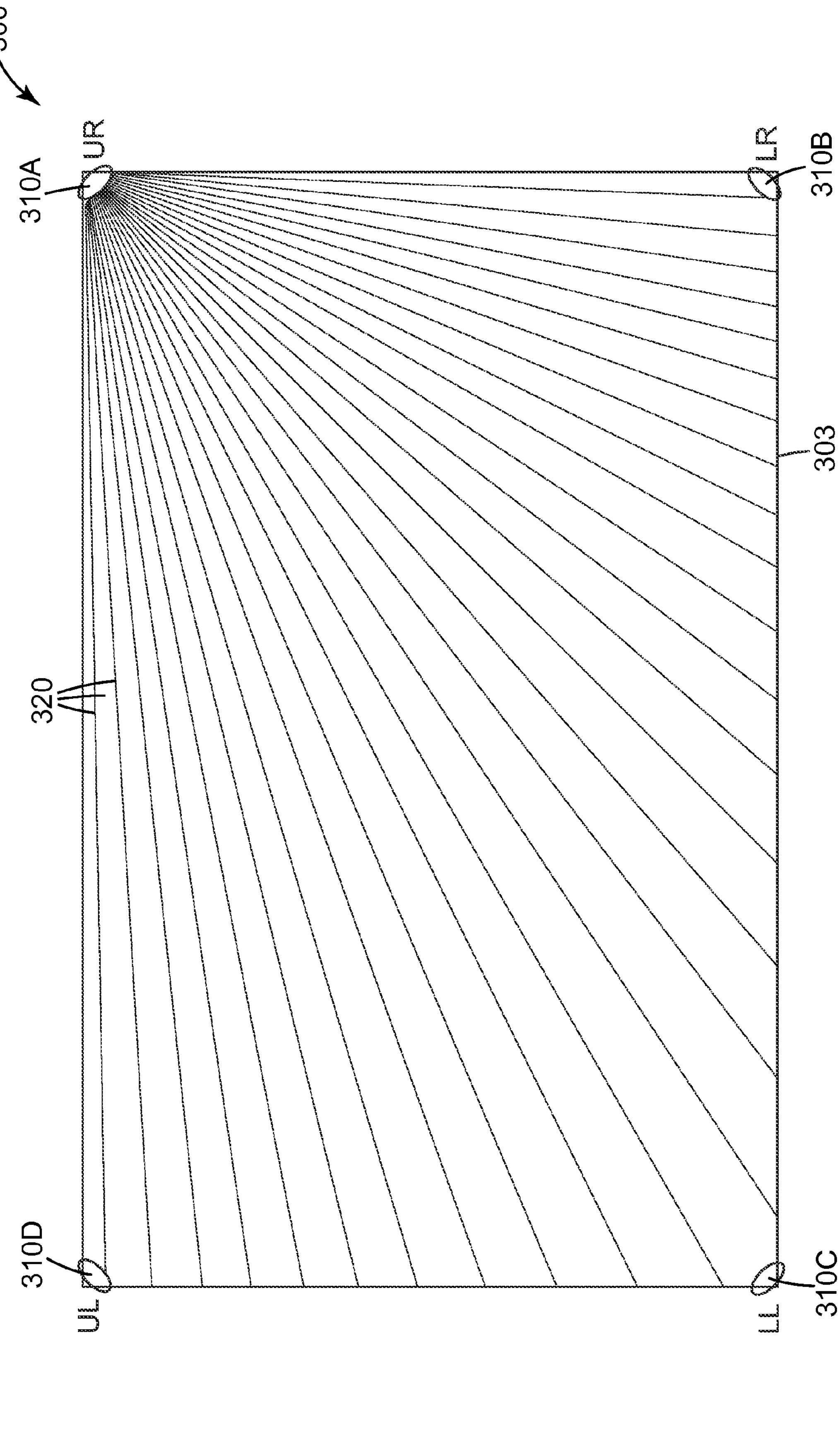


Fig. 3

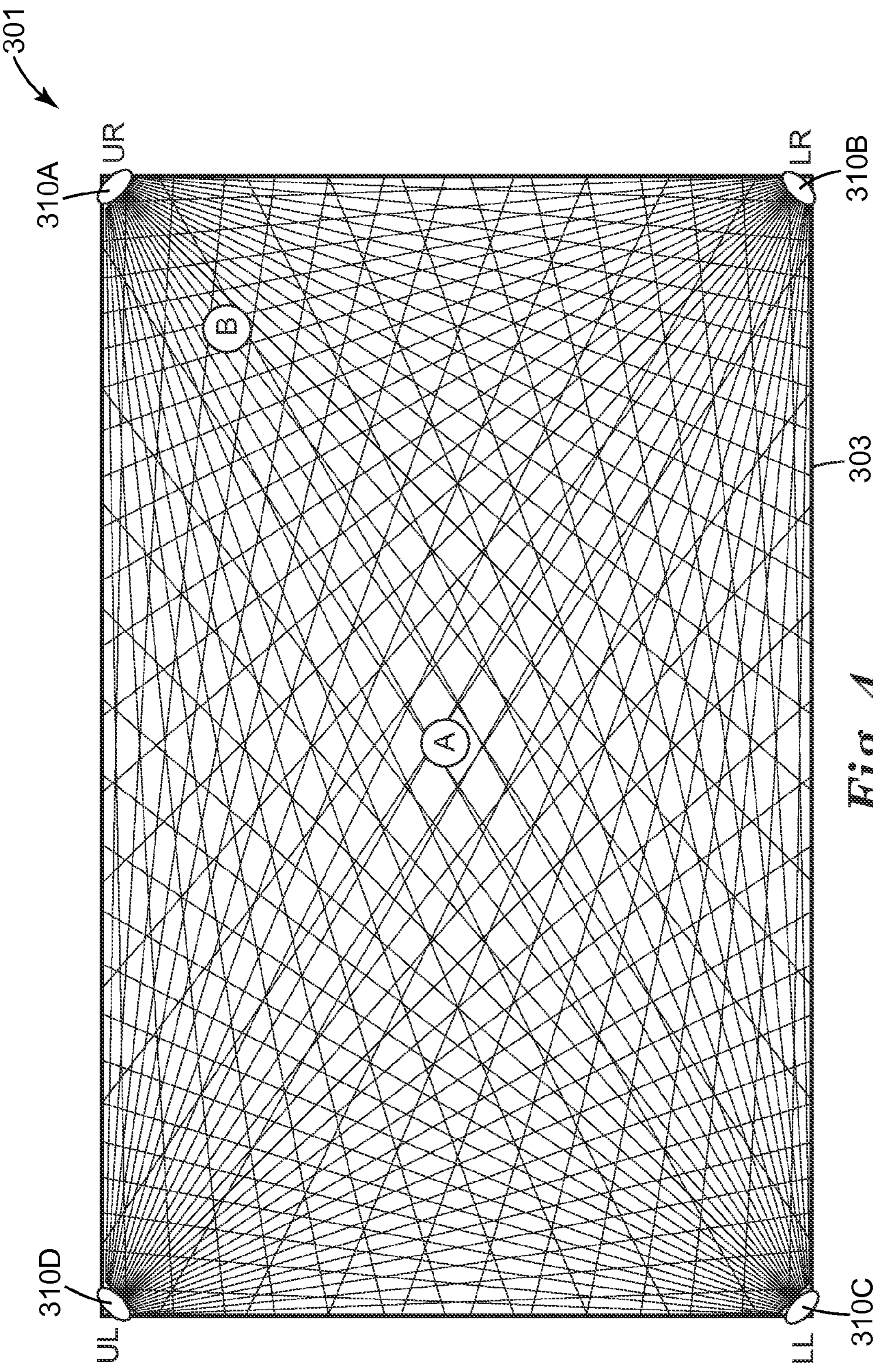


Fig. 4

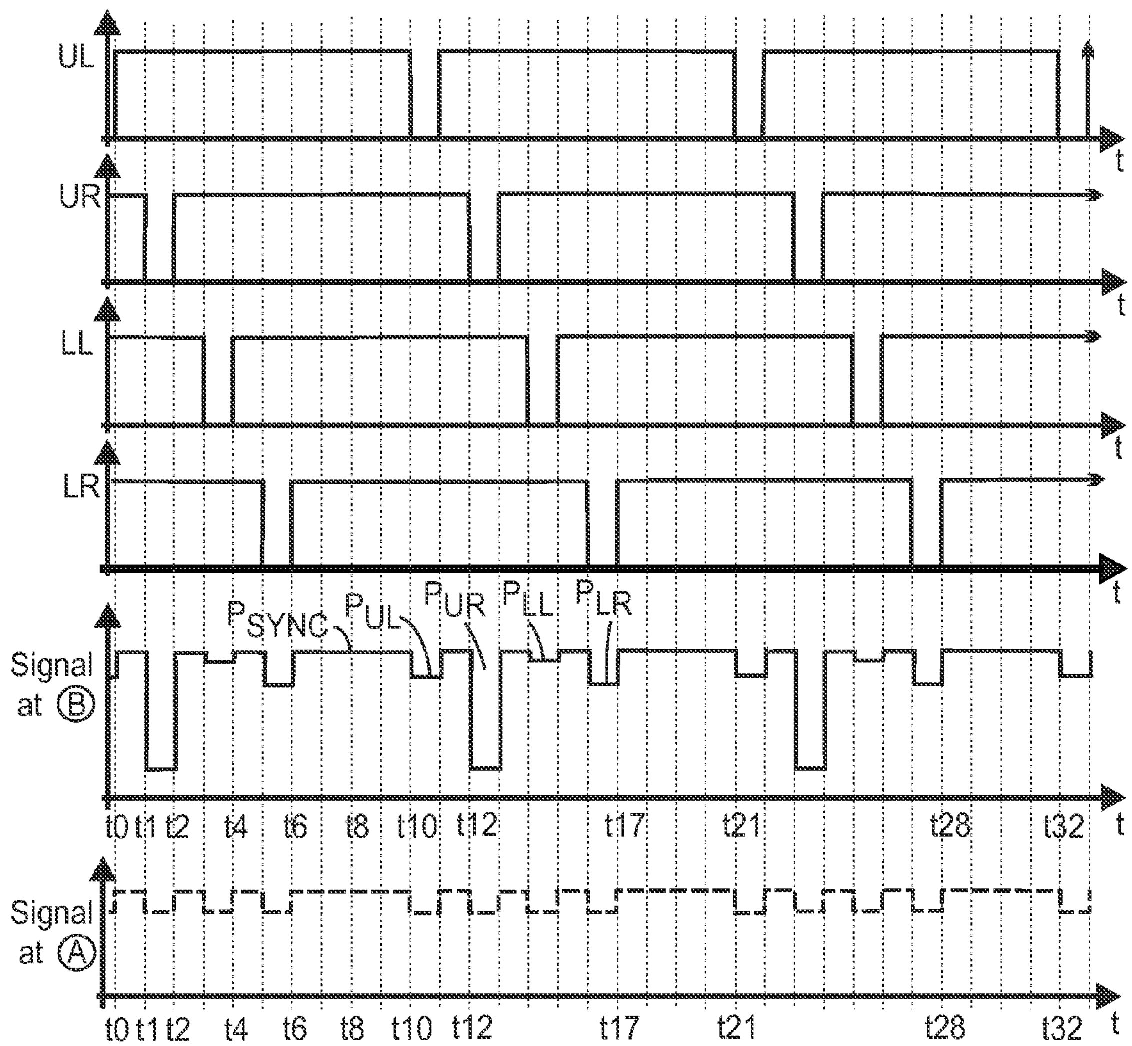
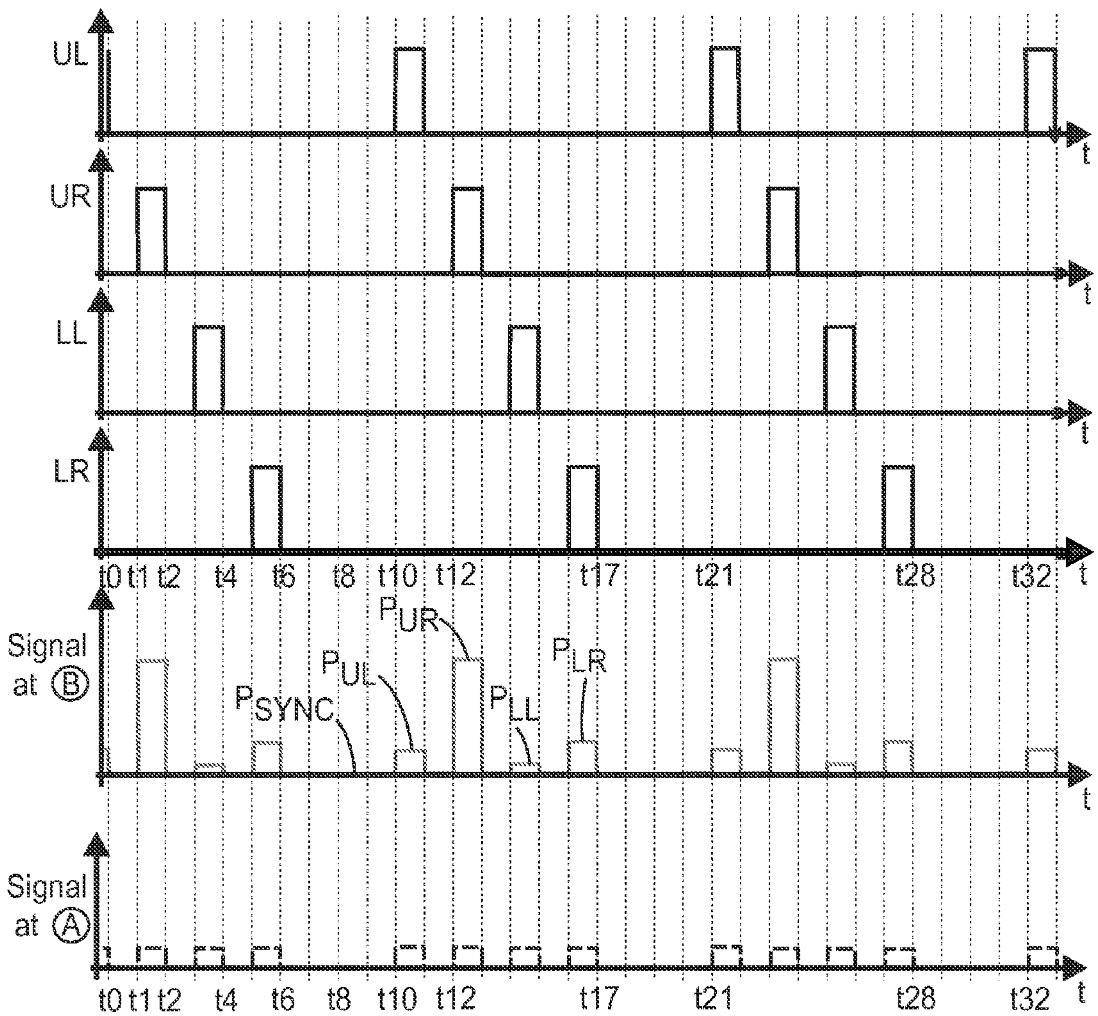

UL
t
UR
t
LL
t
LR
t
P_{SYNC}
P_{UL}
P_{UR}
P_{LL}
P_{LR}
Signal at B
t0 t1 t2 t4 t6 t8 t10 t12 t17 t21 t28 t32 t
Signal at A
t0 t1 t2 t4 t6 t8 t10 t12 t17 t21 t28 t32 t

Fig. 5A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UR
LL
LR
t
t0 t1 t2 t4 t6 t8 t10 t12 t17 t21 t28 t32
Signal at B
P_SYNC
P_UL
P_UR
P_LL
P_LR
Signal at A
t0 t1 t2 t4 t6 t8 t10 t12 t17 t21 t28 t32

Fig. 5B

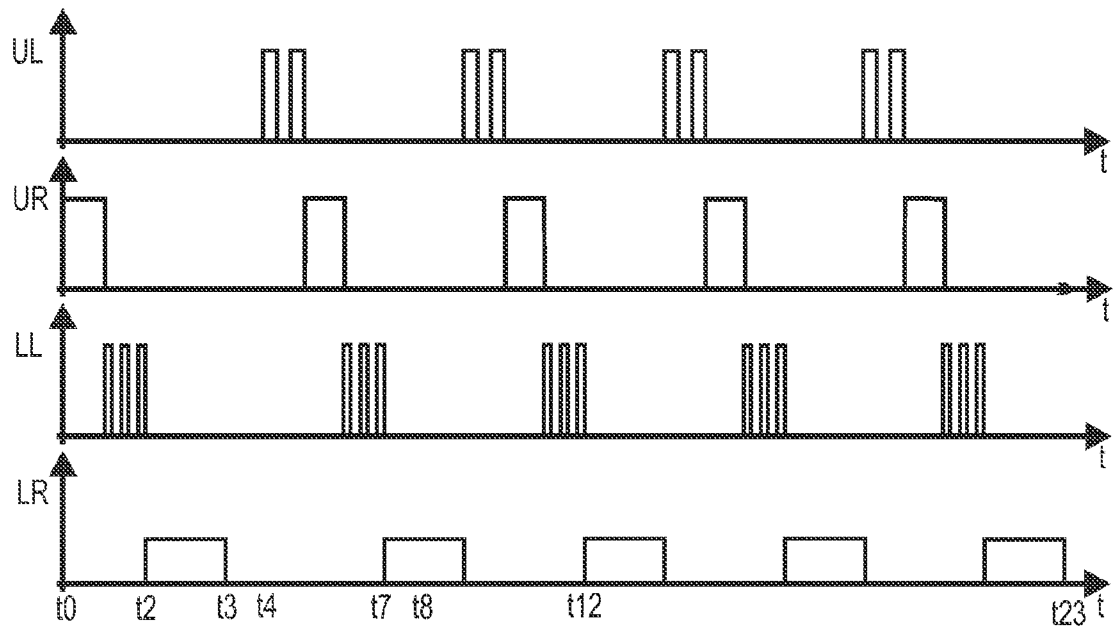

Fig. 6

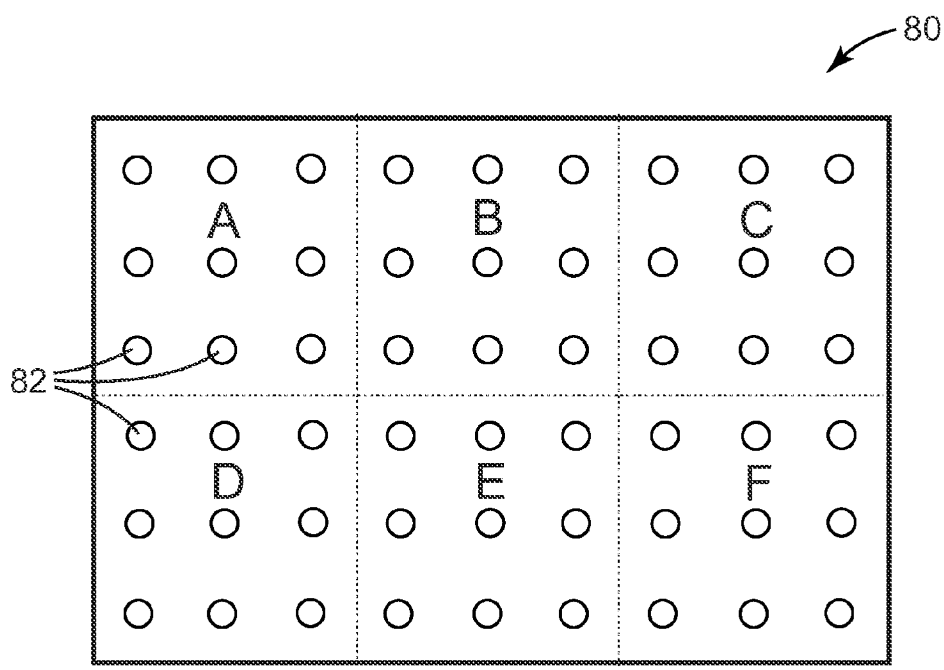

Fig. 8

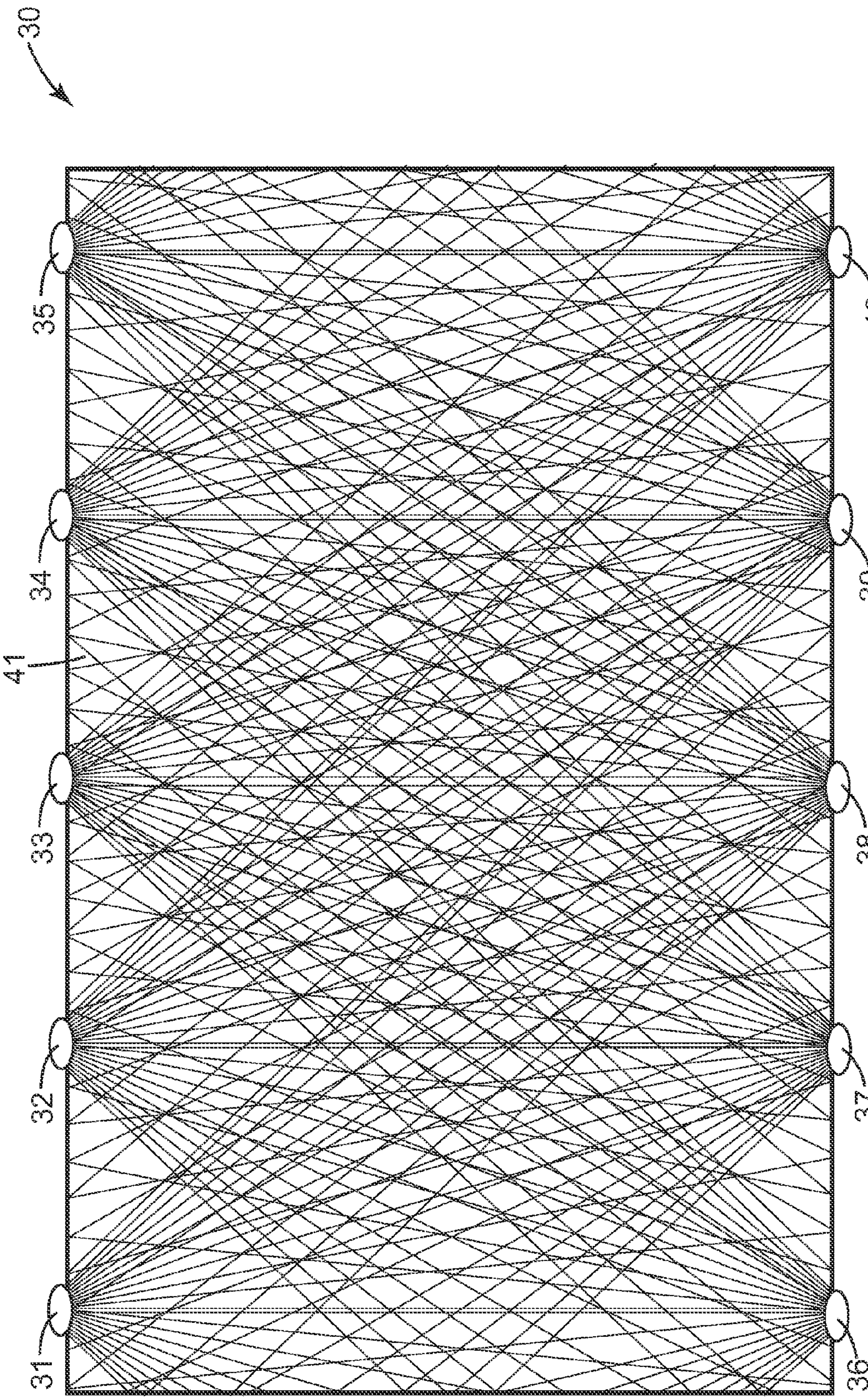

Fig. 7

LIGHT GUIDE FOR BACKLIGHT

CROSS REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Provisional Patent Application No. 61/507,671, filed Jul. 14, 2011, the disclosure of which is incorporated by reference herein in its entirety.

BACKGROUND

Pointing devices of various types are used in almost every computer application today. Some of the pointing devices that have been developed and popularized include:

(1) a mouse;

(2) a trackball;

(3) a transparent-touch screen that overlays the display including resistive and capacitive types;

(4) pressure, capacitive, resistive, or thermal sensitive tablet separate from the display;

(5) beam-breaking detectors surrounding the display;

(6) a light pen based on detection of the raster scan timing of the phosphor refresh beam;

(7) a stylus that incorporates pressure transducers; and

(8) a pen using ultrasonic, stereo tactic or radio frequency triangulation methods.

The various devices developed to position a pointer on a computer screen operate in conjunction with the application software on the computer using an appropriate software driver. Most such drivers try to emulate the conventional X/Y roller mouse. Typically, only positional information is fed to the application software that controls the position of the pointer on the screen.

Pens may offer increased fidelity of user interaction with computer systems. However, depending on implementation, the resolution of pen position determination may be limited to that of the touch-sensitive sensor. Often, touch screens and tablets have a touch resolution that is coarser than the screen resolution of the computer for which they are acting as an input device.

SUMMARY

A light guide for use with an electronically addressable display, such as a liquid crystal display (LCD), which mixes a plurality of signals provided by a backlight components. The mixed signals provide a position-unique signal which uniquely defines positions on the light guide, and which in turn uniquely defines positions on an associated electronically addressable display.

In some embodiments, a stylus or other device may receive the position-unique signals and determine therefrom its position relative to the electronically addressable display. Information indicative of the position may be provided to a host computer which may update the display in response to information provided regarding the stylus's position.

In one embodiment, a light guide for use on a display device is described, comprising a light transmissive substrate; a first and second signal source configured to provide first and second signals to the light transmissive substrate; wherein the light transmissive substrate is configured to mix the first and second optical signals such that positions on the substrate are associated with a position-unique combination of the first and second optical signals.

Related methods, systems, and articles are also discussed. These and other aspects of the present application will be apparent from the detailed description below. In no event, however, should the above summaries be construed as limitations on the claimed subject matter, which subject matter is defined solely by the attached claims, as may be amended during prosecution.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a schematic of an LCD based digitizer system;

FIG. **1**B is a schematic of an emissive display based digitizer system;

FIG. **1**C is a schematic of a projection display based digitizer system;

FIG. **2** is a schematic of a cross-section of an optical stylus;

FIG. **3** is a simplified drawing of a backlight employing position-unique optical signals;

FIG. **4** is a simplified drawing of a backlight employing position-unique optical signals;

FIG. **5**A is a time-axis chart showing representations of position-unique optical signals at various points on a display;

FIG. **5**B is another time-axis chart showing representations of position-unique optical signals at various points on a display;

FIG. **6** is another time-axis chart showing representation of position-unique optical signals at various points on a display;

FIG. **7** is a simplified drawing of a backlight employing position-unique optical signals; and,

FIG. **8** is a simplified drawing of a full-array backlight employing position-unique optical signals.

DETAILED DESCRIPTION

Movement of an optical stylus relative to a display may be measured by sensing position-unique optical signals provided, for example, by a backlight associated with the display. For example, light-emitting elements of an liquid crystal display (LCD)-type display device may be configured to emit position-related signals of light, possibly in a time-varying (modulated) manner, from different positions of the display, such that the combination of two (or more) such position signals at any given point on the display may be sensed by a stylus and used to determine the position of the stylus relative to, or on, the display device.

FIG. **1**A is a schematic of a digitizer system of embodiment A. Display **110** is an electronically addressable light shuttering display, such as an LCD. In LCD embodiments, display **110** includes a backlight **112**, which provides human visible light through LCD panel **111**. Backlight **112** includes at least two, and possible more, emitters which emit modulated light signals into components of display **110**. The positional-modulated emitters may also emit visible light through the LCD, or they may emit non-visible light. The positional modulation of emitters, and the associated modulation of light signals, minimally affect the visible image being displayed by the electronically addressable display.

Optical stylus **120** includes an optical sensor coupled to a stylus body. The optical sensor receives the modulated light signals, which are processed by an optical stylus processor that may also be included within optical stylus **120**, to determine the position of the optical sensor upon display **110**. Communications link **124** communicatively couples stylus **120** to computing device **130**, which may be a notebook or tablet computer, which is in turn communicatively coupled to display **110**. Communications link **124** may comprise several conductors, or a radio link such as that implementing the wireless communications protocol referred to as Bluetooth™. Optical stylus processor includes electronics necessary to provide electrical signals indicative of the sensed signals computing device **130**. Communications link **135** communicatively couples display device **110** with computing device **130**. This coupling may be by a plurality of conductors or may be by radio. Communications link **136** communicatively couples backlight **112** with computing device **130** for the purpose of controlling backlight emitters. While computing device **130** is shown separate from display device **110**, other integral combinations are possible, where both the display device and the computer are within the same chassis (as would be the case, for example, with tablet-type computers, all-in-ones, and laptops).

FIG. **1**B is a schematic of a digitizer system **140** of embodiment B. Emissive display **141** is an electronically addressable visible light emitting display that is at least partially transparent or translucent at some wavelengths of light, for example infra-red. Examples of this display type include plasma displays and transparent organic light emitting diode (OLED) displays. Backlight **142**, provides non-visible light through emissive display panel **141**. Backlight **142** includes at least two, and possible more, emitters, which emit modulated light signals through display **141**. The emitters, and the associated modulation of light signals, are preferably non-visible so they minimally affect the visible image being displayed by emissive display **141**.

FIG. **1**C is a schematic of a digitizer system **150** of embodiment C. Display surface **151** is a light diffusing surface that is transparent or translucent at some non-visible wavelengths of light, and may be translucent at visible wavelengths of light. Examples of this display type include rear projection displays and front projection displays. In a front projection embodiment, visible light **158** is reflected from display surface **151**. In a rear projection embodiment, visible light **159** is passes through backlight **152** and is diffused by display surface **151**. Backlight **152** provides position-unique non-visible light (e.g. IR) through display surface **151**. Backlight **152** includes at least two, and possible more, emitters, which emit modulated light signals through display surface **151**. The emitters, and the associated modulation of light signals, minimally affect the visible image being displayed on the display surface. Backlight **152** is depicted with a flat cross section, though back lighting may also be projected onto surface **151** from a distance.

FIG. **2** depicts a cross sectional view of an optical stylus **50** that can be used in the present invention. Lens **52** focuses light **55** from a display through aperture **53** onto signal detector **54**, which is preferably a photodiode, phototransistor, or may be a charge coupled device (CCD) array, for example (these sensing components referred to collectively as an optical sensor).

Stylus signal detector **54** is communicatively coupled to optical signal processor **58**. Optical signal processor receives signals from optical detector **54** through interconnection **56**. In embodiments where detector **54** is a photodiode or phototransistor, processor **58** measures a signal indicating the intensity of display light **55**. In embodiments where detector **54** is a 2D image detector such as a CCD, processor **58** measures a two dimensional map of intensities of display light **55**.

In some embodiments, stylus **50** may incorporate a photodiode or phototransistor and also a CCD. For example, a photodiode may detect position-modulated IR light while a CCD views the visible pixels of the display.

The stylus **50** can have a long focal length so it remains focused on a display surface over ranges including when the stylus is contacting the front surface up to when the stylus is several meters from the display surface, for example. Stylus body **51** supports signal detector **54**, lens **52**, and processor **58**. Stylus **50** may include optional components such as a tip switch or barrel switch, not shown.

FIG. **3** is a drawing of a backlight **300** having light guide **303** and four optical signal emitters, positioned proximate to each corner of the light guide. Light guide **303** is a component commonly used in LCDs. It typically comprises one or more plates of transparent or translucent material. Typical light guides are described in US Patent Application No. 20100014027 and U.S. Pat. Nos. 7,532,800 and 7,699,516. A light guide may further include a light reflecting rear surface, and light directing films. Examples of light directing films include brightness enhancement films sold by 3M Corporation, St. Paul, Minn., under the trade names Vikuiti BEF I, BEF II, and BEF III. Backlight **300** would be positioned behind a display, in one embodiment. Positioning the light emitters around the perimeter of the display is referred to as edge lighting. Individual positional emitters provide optical signals that may be modulated with various pulse sequences, creating light signals that may be resolved to define unique positions on the display. The backlight shown in FIG. **3** has four emitters **310**A-**310**D that provide optical positional signals, positioned at each of the corners. In some embodiments, emitters may additionally provide the visible light for the display, in displays that require backlighting, such as an LCD display. In other embodiments, positional emitters may be combines with additional lighting elements included in the edge lighting that are not providing optical positional signals. Additionally, while four emitters are shown in FIG. **3**, other embodiments having for example only two emitters are possible.

For ease of representation, only representations of signals emitted from upper right ("UR") emitter **310**A are shown in FIG. **3**. Emitter **310**A, in this embodiment, comprises an LED, providing light using light signals modulated at a frequency specific to emitter **310**A. Other emitters **310**B, **310**C, and **310**D, corresponding to locations Lower Right (LR), Lower Left (LL) and Upper Left (UL) would function similarly, but with different modulation waveforms or phase from one another. Light guide **303** provides distribution of the light signals from emitters **310**A-**310**D across the area of light guide **303**, and out of light guide **303** in a direction toward the user. Emitters, if integral to the backlight scheme of, for example, an LCD display, are typically located behind the display (from the perspective of a user who is located in front of the display), to thusly provide light through the individual pixels of said display. However, other configurations are possible. For example, in embodiments B and C above where the emitters do not additionally provide for backlighting, a separate substrate receiving signals provided by the emitters could be located on top (i.e., user-side) of the display, as a digitizer overlay component.

Optical positional signals **320** are represented emanating from emitter **310**A. Signals emanating from other emitters may have different wavelengths or they may (and would typically) be of the same wavelength (color) light, but they may have unique modulation wave shape.

FIG. **4** is a drawing of backlight **301** having four optical signal emitters, positioned proximate to each corner of a rectangular display. It is similar to backlight **300** (FIG. **3**), but additionally includes representation of optical positional signals associated with each of the emitters **310**A-**310**D. FIG. **4** shows point A and point B, which are referred to in relation to subsequent figures.

FIG. **5***a* is a graph showing light signals provided by emitters **310**A-**310**D. Emitter UL (**310**D) is shown having a first waveform modulation; emitter UR (**310**A) is shown having a second waveform modulation; emitter LL (**310**C) is shown having a third waveform modulation; and emitter LR (**310**B) is shown having a fourth waveform modulation. All four emitters are on for four clock periods during synchronization period between t**6** and t**10**. This provides a reference level for measuring proportions of light, and it provides a synchronizing signal that an untethered stylus can use as a time reference to determine when each light source is emitting. A representation of the summation of the four waveforms at various times is shown at the bottom of the graph, in one case associated with point A, and in another case associated with point B. An optical sensor (as in an optical stylus) would detect the sum of the signals emitted from the four emitters in proportions corresponding to the location of the optical sensor on the display. For example, an optical sensor positioned at point A (referring to FIG. **4**) would detect equal amounts of light from each emitter.

But a sensor positioned at point B would detect more light from source UR, followed by LR, UL, and LL. This phenomenon means a ratiometric approach may be used to determine the position of the optical sensor based on the relative magnitudes of the received signal, which changes as a function of how near they are to particular emitters.

For example with reference to FIG. **5***a*, signal B (corresponding to light measured at point B) is constant and maximum during the sync period from t**6** to t**10**, then each of the four emitters UL, UR, LL, then LR is pulsed off in sequence between time t**10** and time t**17**. As each emitter is pulsed off, there is a corresponding reduction in light received at point B. The changes in light are indicated by the magnitudes of pulses P_{UL}, P_{UR}, P_{LL}, and P_{LR}, in FIG. **5**. In each case, the pulse magnitude (deviation from the P_{SYNC} level) is proportional to the relative contribution of light from each emitter, which is inversely proportional to the relative distance from each emitter.

Signal A (corresponding to light measured at point A) shows four pulses between t**10** and t**17**, and all pulses are equal in magnitude. This indicates equal light received from the four emitters, which indicates that point A is equally distant from each of the emitters UL, UR, LL, then LR.

White LEDs may be used as emitters **310**A-**310**D. Given the modulation shown in FIG. **5***a*, the LEDs have a 91% duty cycle so they contribute to the user-visible light emitted through, for example, an LCD, as well as providing optical positional signals used to determine the position of a stylus proximate the display. Infra-red (IR) LEDs may also or instead be used as emitters **310**A-**310**D, which may be preferable for Embodiments A, B, and C. IR emitters used with Embodiment A may, in some embodiments, have a wavelength greater than 900 nM. Longer wavelength light penetrates LCD display pixels in the "on" state or the "off" state, so position signals may be measured relatively independent of the image displayed on the LCD. For example, LEDs that emit 950 nM IR are readily available.

In embodiments using non-visible light emitting LEDs to generate position-unique signals, the duty cycle of the LED would preferably be reduced to save power, because such IR LEDs do not contribute to user-visible light emitted from the display. FIG. **5***b* shows a graph illustrating representative signals from such an embodiment. FIG. **5***b* is similar to **5***a* except the duty cycle of emitters UL, UR, LL, and LR reversed to 10% or less, rather than 91%.

In addition to locating a stylus relative to the surface of a single display, variations in pulse codes of FIG. **5**A may be used to discriminate one display from another. For example, in a system with two or more displays, the stylus may detect which display is within its field of view, and communication from the stylus to its host computer system includes a display ID and corresponding multi-display coordinates. Other functions may include limiting a stylus to operate with one display but not with another.

Pulse codes of multiple displays may be made unique from one another in a variety of ways. For example, one display backlight may use IR pulses as shown in FIG. **5**A while another display's backlight emits the same waveform, but at a different fundamental frequency, (the time period of a cycle from t**6** to t**17** is different). Another display may be differentiated by changing only the time period of the sync pulse P_{SYNC} (from t**6** to t**10**). Another display may be differentiated by changing the shape of pulses P_{UL}, F_{UR}, P_{LL}, and P_{LR}, for example each of pulses P_{UL}, P_{UR}, P_{LL}, and P_{LR}, may comprise two pulses rather than one, as is shown in the UL waveform of FIG. **6**, or three pulses rather than one, as is shown in the LL waveform of FIG. **6**. Additional waveform variations may be used separately or in combination to generate display-unique light signals.

FIG. **6** shows a graph illustrating representative signals from another alternative embodiment. Rather than equal shaped, equally spaced emitter pulses with different phases, the pulses shown in FIG. **6** have various shapes, which help distinguish which emitter is contributing each portion of a signal received by an optical sensor.

It should be realized that the optical positional signals represented as waveforms in FIGS. **5**A and **5**B and **6** may be used in various combinations and any of the signals may be used with any wavelength light sources. Also, other modulation methods may be used, including amplitude modulation, frequency or phase modulation, variations of pulse coding, or sine waves with fixed frequency and amplitude or varying frequency and/or amplitude, and variations in wavelength of light emitted from different emitters. Modulated signals provided by emitters are preferably imperceptible or minimally perceptible to the human eye, due to the frequencies of modulation or to the wavelength of light that is modulated.

FIG. **7** is a drawing of backlight **30** including ten optical signal emitters, positioned along the top and bottom edge of light guide **41**. This is a simplified representation of an LCD backlight: in practice LCD backlights may have many more such emitters. This basic layout, however, is typical of backlights using LED edge lighting. Rays representing light from emitters are shown for illustration purposes. Optical signal emitters **31**-**40** may be used to locate a stylus if light from at least some of the emitters is modulated differently than others. For example, emitters **31**-**40** may all emit the same color and average brightness in order to perform their respective backlighting function, but additionally they may be modulated with signals that result in optical positional signals that provide for position-unique signals that may be sensed at any position on the display. In one embodiment, each of the emitters **31**-**40** may modulate its respective optical positional signals uniquely. Alternatively, some of the emitters may modulate the same as others, provided that the sum of signals at every location on the surface of backlight **30** comprises a unique combination from the ten emitters **31**-**40**. Further emitters **31** and **40** overlap minimally so they may emit identically modulated light. Emitters **35** and **36** may also emit identically modulated light because their optical positional signals may be combined with optical positional signals from other emitters such that the total emitted light at any given point on backlight **30** will be unique.

FIG. **8** shows full array backlight **80** similar to those used with some LCD displays. Backlight **80** is divided into six areas, A, B, C, D, E, and F. Emitters **82** each provide unique modulation of the light they provide, similar to other embodiments described herein.

Rather than white light LEDs, a further embodiment uses LED lasers as an edge light. The laser beam may be scanned across the light guide of an LCD display, refracting at grid lines in the light guide so its light emits through the visible display at predetermined places as the laser beam is scanned. The refracted portion of the laser beam may be detected by the optical sensor.

Unless otherwise indicated, all numbers expressing quantities, measurement of properties, and so forth used in the specification and claims are to be understood as being modified by the term "about". Accordingly, unless indicated to the contrary, the numerical parameters set forth in the specification and claims are approximations that can vary depending on the desired properties sought to be obtained by those skilled in the art utilizing the teachings of the present application. Not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques. Notwithstanding that the numerical ranges and parameters setting forth the broad scope of the invention are approximations, to the extent any numerical values are set forth in specific examples described herein, they are reported as precisely as reasonably possible. Any numerical value, however, may well contain errors associated with testing or measurement limitations.

Various modifications and alterations of this invention will be apparent to those skilled in the art without departing from the spirit and scope of this invention, and it should be understood that this invention is not limited to the illustrative embodiments set forth herein. For example, the reader should assume that features of one disclosed embodiment can also be applied to all other disclosed embodiments unless otherwise indicated. It should also be understood that all U.S. patents, patent application publications, and other patent and non-patent documents referred to herein are incorporated by reference, to the extent they do not contradict the foregoing disclosure.

The invention claimed is:

1. A light guide for use on a display device, comprising:

a light transmissive substrate;

a first and second signal source configured to provide first and second optical signals to the light transmissive substrate;

wherein the light transmissive substrate is configured to mix the first and second optical signals such that positions on the substrate are associated with a position-unique combination of the first and second optical signals, wherein the light guide is a backlight of the display device.

2. The light guide of claim **1**, wherein the light guide is a backlight to a liquid crystal electronically addressable display device.

3. The light guide of claim **2**, wherein the first and second optical signals have a first and second modulation, respectively.

4. The light guide of claim **3**, wherein the first and second signals' modulation frequency is 30 Hz or more.

5. The light guide of claim **4**, wherein the first and second signals' modulation frequency is 100 Hz or more.

6. The light guide of claim **3**, wherein the first and second signals have first and second waveforms, respectively.

7. The light guide of claim **3**, wherein the first and second signal source are light emitting diodes.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 9,292,131 B2
APPLICATION NO. : 13/545053
DATED : March 22, 2016
INVENTOR(S) : Geahgan

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Specification

Column 6

Line 13 (Approx.), Delete "F_{UR}," and insert -- P_{UR}, --, therefor.

Signed and Sealed this
Twenty-fifth Day of October, 2016

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office